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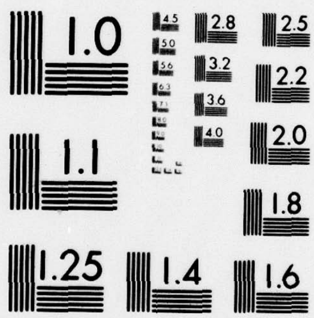

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1977 ROBIN PROGRAM - USER'S MANUAL

JULY 1979

Prepared by

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Under Contract DAAD07-78-C0020
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Robin 77 or revised High Altitude Robin Program is specifically designed for computer reduction of Robin flights which attain an apogee of approximately 125 km, and are tracked by an FPS/16 radar. The program also provides accurate reduction for Robin flights attaining other apogees between 65 and 150 km. If a passive sphere other than the 1-m Robin (approximately 115 g) is used, reduction with this program is still possible. There may be times, however, when drag coefficients are not available and thus density, temperature,

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20. ABSTRACT (cont)

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and pressure cannot be computed. The time of fall test used to determine sphere collapse is not used for spheres with dimensions that differ from the Robin.

At each second of flight, the program calculates altitude, wind components and direction, density, temperature, and pressure, the RMS noise error in winds, density, temperature and pressure, and other balloon dynamics.

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SECTION 1

DESCRIPTION OF 1977 ROBIN PROGRAM

The 1977 ROBIN program is an update of the April 1972 HIROBIN program. The 1977 program contains several changes from the 1972 version. The changes were made in order to eliminate the Mach 1 and supersonic bias, to extend and modify the drag table so that the temperatures of sphere and Datasonde flights were in agreement, to improve the method of calculating RMS wind and thermodynamic errors, to improve the first guess at temperature, and to standardize input constants. A discussion of the changes made and how they were incorporated into the 1977 ROBIN program is contained in the following paragraphs.

Removal of Supersonic and Mach 1 Bias

The 1977 ROBIN program is designed to remove both the supersonic and Mach 1 bias in all parameters - density, pressure, temperature, and winds. The technique used to remove bias is to simulate the bias by a theoretical trajectory and then subtract this bias from the standard ROBIN output. Thus the 1977 ROBIN (with respect to bias error removal) is essentially the 1972 HIROBIN with additional subroutines to calculate and subtract the bias error. Details are as follows (see Figure 1). The editing program and the descending altitude subroutine which determines where data processing of the flight begins have not been changed in the 1977 program. An initial position and velocity of the sphere, however, are calculated from the radar data immediately after the determination of five consecutive descending altitudes. From this initial position and velocity, a theoretical sphere trajectory is generated by assuming the sphere fell in the 1976 Standard Atmosphere with no winds present. The theoretical trajectory is terminated at 60 Km since both Mach 1 and supersonic bias occur above this altitude. The theoretical profile of (t,X,Y,Z) coordinates is then treated as if it represented radar coordinates. Logic of the 1972 HIROBIN program with the

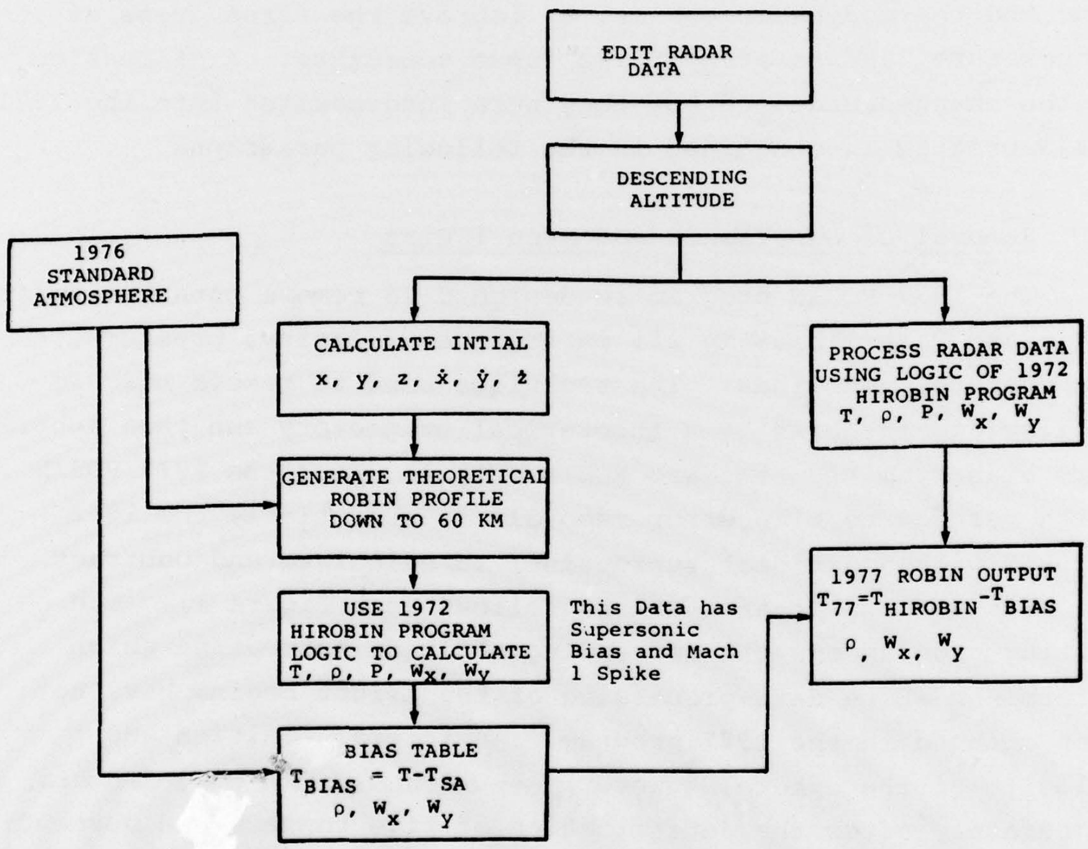

Figure 1. 1977 ROBIN Program

19-21, 51-35 filters is used to generate atmospheric parameters of winds, temperature, density, and pressure from the theoretical trajectory. Any differences between the computed parameters and the 1976 Standard Atmosphere values are the bias errors resulting from the filters. These differences in density, temperature, and winds are stored in a bias correction array. Bias errors in pressure are not stored since using the ideal gas law, pressure can be determined directly from temperature and density measurements. After generation of the bias correction table, processing of the radar data continues in the same manner as was done in the 1972 HIROBIN program. The 1977 output is obtained by subtracting the bias correction table from the radar processed data. The correction is applied by interpolation of the bias error table at each altitude where processed tracking data occurs - except for altitudes between Mach 1.3 and Mach .85. During this region, where the Mach 1 spike occurs, the bias correction table is interpolated based on Mach number.

A feature of the bias removal procedure is its ability to remove both the supersonic bias and Mach 1 spike. Examples of typical bias errors appear in Figure 2.

Drag Table

The drag table used in the 1977 ROBIN program is an extended and modified version of the Bailey and Hiatt drag table used in the 1972 HIROBIN. The drag table was extended in the region adjacent to Mach 2 and Reynolds Number 1600 so that those high apogee flights that in the past went out of the drag table would remain within given drag values. These extended drag coefficients were obtained from Bailey and Hiatt's ballistic sphere measurements[1].

Changes were made to the subsonic drag coefficients between Mach 0 and 0.5 and Reynolds Numbers between 5000 and 35,000. The purpose of these changes, as explained in Reference 2, was to bring sphere temperature measurements into agreement with Datasonde measurements in the region between 32 and 58 Km.

ALT(m)	MACH#	WE (m/sec)	WN (m/sec)	DENSITY (g/m^3)	TEMP(°k)
98437.292145	2.635602	-6.370531	2.566609	.00000003	0.000000
97724.561016	2.721468	-6.377136	2.402351	.00000004	-.424353
97006.034992	2.752645	-5.792589	2.183636	.00000004	-.395935
96280.067575	2.779144	-5.136235	1.936902	.00000004	.012494
95546.790044	2.807399	-4.431017	1.670590	.00000005	-.115657
94806.569454	2.842493	-3.700956	1.393965	.00000006	-1.276016
94059.799905	2.872679	-2.968973	1.115604	.00000008	-2.112291
93306.756115	2.892304	-2.255565	.844031	.00000009	-1.950179
92548.063558	2.912352	-1.577355	.585139	.00000010	-2.051592
91784.137772	2.930671	-.946765	.344070	.00000013	-2.332711
91015.742464	2.947659	-.372705	.124447	.00000016	-2.953476
90243.409411	2.955078	.139096	-.071320	.00000018	-2.720051
89467.962302	2.956312	.565463	-.241313	.00000020	-2.132337
88690.217473	2.956305	.965286	-.386449	.00000023	-1.799865
87911.356409	2.946563	1.278324	-.505276	.00000024	-.716141
87132.304263	2.929609	1.528035	-.598896	.00000022	.757957
86354.344323	2.909546	1.715455	-.668365	.00000020	2.043479
85578.332464	2.887954	1.845056	-.715235	.00000021	2.080890
84807.165264	2.855160	1.921404	-.741230	.00000022	2.130649
84040.822933	2.812820	1.949341	-.748292	.00000018	2.964337
83281.383327	2.765463	1.933735	-.738387	.00000013	3.794350
82530.445214	2.715499	1.879120	-.713394	.00000008	4.281828
81789.791437	2.662800	1.789985	-.675195	.00000004	4.439206
81060.363545	2.607178	1.671329	-.625872	.00000001	4.292369
80345.296862	2.548195	1.528810	-.567713	-.00000000	3.919131
79644.571836	2.482574	1.368271	-.503081	-.00000004	3.822123
78960.106407	2.408231	1.195450	-.434263	-.00000019	4.659410
78293.287320	2.331333	1.015603	-.363426	-.00000036	5.332569
77645.356105	2.254347	.833265	-.292336	-.00000050	5.545744
77017.232236	2.176817	.652262	-.222532	-.00000063	5.496977
76409.314062	2.097712	.475563	-.155222	-.00000075	5.387361
75823.471218	2.017936	.305577	-.091350	-.00000090	5.305520
75258.620739	1.941936	.144040	-.031562	-.00000091	4.439379
74715.235613	1.864033	-.007807	.023627	-.00000099	4.065495
74193.131429	1.785456	-.149136	.074006	-.00000102	3.493546
73692.012503	1.711530	-.279371	.119403	-.00000080	1.572036
73211.143021	1.649412	-.397747	.159650	-.00000061	.716095
72749.984927	1.573657	-.503390	.194560	-.00000101	1.959512
72307.559021	1.503365	-.595146	.223981	-.00000092	1.255562
71883.268864	1.443563	-.671742	.247629	-.00000101	1.225149
71476.115395	1.393062	-.732576	.265517	-.00000104	1.013533
71085.125046	1.327503	-.777810	.277660	-.00000106	.826599

Figure 2. Typical Bias Error

The drag table used in the 1977 ROBIN program is shown in Figure 3.

1976 Standard Atmosphere

The calculation of pressure and temperature in the ROBIN program requires a first guess of temperature (usually near 95 Km). In the 1972 HIROBIN program the initial temperature was obtained from the 1962 Standard Atmosphere. In the 1977 ROBIN, the first guess is taken from the 1976 Standard Atmosphere. The 1976 Standard Atmosphere is also used in the 1977 ROBIN program for the generation of the theoretical trajectory from which the supersonic and Mach 1 bias correction table is generated.

RMS Errors

The equation used in the 1972 HIROBIN program to estimate the radar error failed to take into account the correlation in velocities introduced by the filtering process. Consequently, the error estimates were too small by fifty percent or more at the higher altitudes. Reference 3 discusses the correlated error problem and provides an equation for estimating the influence of the correlated errors. The 1977 ROBIN has been modified to include the correlated error term. Thus, assuming that the FPS/16 radar performs according to specifications, the 1977 ROBIN will provide an accurate estimate of wind and thermodynamic errors arising from the radar track.

Gravitational Constant

To maintain consistency with other programs used in the reduction of meteorological data, the equation used to calculate the gravitational constant in the 1977 ROBIN program is

$$G_S = -9.780356\left(1+5.2885 \times 10^{-5}\left(\sin^2(\Phi)\right) - 5.9 \times 10^{-8}\left(\sin^2(2\Phi)\right)\right),$$

where Φ is latitude. No discernable change in thermodynamic or wind data output results from the modification of the gravitational constant.

DRAG TABLE (1AUG 1977)

MACH	REYNOLDS NUMBER 10.	20.	30.	40.	50.	75.	100.	150.	200.	300.	400.	500.	600.	800.	1000.
4.60	1.673	1.604	1.535	1.491	1.449	1.384	1.342	1.289	1.250	1.199	1.171	1.142	1.132	1.104	1.075
4.40	1.683	1.612	1.541	1.491	1.452	1.392	1.347	1.292	1.252	1.200	1.171	1.144	1.134	1.106	1.078
4.20	1.697	1.622	1.547	1.495	1.458	1.400	1.352	1.298	1.254	1.202	1.171	1.147	1.136	1.108	1.080
4.00	1.720	1.640	1.555	1.503	1.463	1.410	1.358	1.302	1.259	1.207	1.175	1.150	1.138	1.110	1.087
3.80	1.749	1.658	1.567	1.519	1.473	1.420	1.366	1.310	1.266	1.212	1.184	1.157	1.141	1.111	1.088
3.60	1.780	1.680	1.580	1.533	1.485	1.430	1.375	1.319	1.275	1.220	1.192	1.163	1.149	1.122	1.095
3.40	1.809	1.703	1.597	1.548	1.498	1.444	1.390	1.330	1.287	1.230	1.202	1.173	1.158	1.130	1.101
3.20	1.841	1.728	1.615	1.564	1.512	1.456	1.400	1.341	1.298	1.242	1.214	1.186	1.170	1.140	1.109
3.00	1.870	1.753	1.636	1.582	1.528	1.471	1.414	1.355	1.310	1.257	1.227	1.196	1.179	1.146	1.113
2.80	1.903	1.780	1.657	1.601	1.545	1.487	1.429	1.368	1.322	1.270	1.237	1.203	1.186	1.153	1.120
2.60	1.941	1.810	1.679	1.621	1.562	1.502	1.442	1.382	1.337	1.282	1.246	1.210	1.192	1.157	1.122
2.50	1.958	1.825	1.692	1.632	1.572	1.511	1.450	1.390	1.342	1.288	1.251	1.213	1.195	1.160	1.124
2.40	1.976	1.841	1.706	1.644	1.582	1.520	1.458	1.397	1.350	1.293	1.255	1.217	1.199	1.162	1.125
2.30	1.999	1.860	1.721	1.657	1.592	1.529	1.465	1.403	1.356	1.298	1.259	1.219	1.200	1.163	1.126
2.20	2.023	1.880	1.737	1.671	1.604	1.538	1.472	1.410	1.361	1.302	1.262	1.221	1.202	1.163	1.125
2.10	2.046	1.901	1.756	1.687	1.618	1.549	1.480	1.418	1.368	1.306	1.265	1.223	1.203	1.164	1.124
2.00	2.077	1.927	1.777	1.705	1.633	1.562	1.490	1.422	1.372	1.307	1.265	1.222	1.202	1.162	1.122
1.95	2.090	1.940	1.790	1.717	1.644	1.568	1.496	1.427	1.374	1.306	1.264	1.221	1.200	1.158	1.120
1.90	2.107	1.956	1.805	1.731	1.658	1.580	1.502	1.430	1.376	1.305	1.263	1.220	1.199	1.157	1.119
1.85	2.123	1.972	1.821	1.746	1.671	1.590	1.510	1.432	1.378	1.302	1.260	1.217	1.196	1.154	1.116
1.80	2.142	1.990	1.838	1.762	1.686	1.603	1.519	1.435	1.379	1.300	1.258	1.215	1.194	1.152	1.112
1.75	2.169	2.007	1.859	1.780	1.700	1.613	1.527	1.438	1.379	1.298	1.253	1.211	1.191	1.151	1.110
1.70								1.442	1.380	1.297	1.245	1.210	1.179	1.141	1.106
1.65								1.443	1.378	1.292	1.240	1.205	1.173	1.137	1.100
1.60								1.443	1.376	1.287	1.234	1.197	1.167	1.132	1.095
1.55								1.444	1.373	1.280	1.227	1.190	1.160	1.120	1.090
1.50								1.445	1.369	1.273	1.218	1.184	1.154	1.117	1.086
1.45								1.445	1.365	1.266	1.209	1.174	1.146	1.108	1.079
1.40								1.444	1.359	1.257	1.198	1.162	1.136	1.098	1.072
1.35								1.442	1.355	1.249	1.186	1.150	1.123	1.081	1.061
1.30								1.440	1.347	1.238	1.172	1.132	1.107	1.068	1.046
1.25								1.437	1.339	1.230	1.160	1.115	1.085	1.050	1.030
1.20								1.436	1.327	1.214	1.143	1.095	1.070	1.034	1.011
1.15								1.432	1.315	1.197	1.125	1.076	1.052	1.014	0.990
1.10								1.426	1.298	1.180	1.106	1.057	1.032	0.993	0.968
1.05								1.414	1.281	1.156	1.080	1.037	1.013	0.972	0.946
1.00								1.377	1.247	1.119	1.052	1.008	0.987	0.945	0.916
0.95								1.175	1.063	0.952	0.900	0.857	0.837	0.798	0.773
0.90								1.088	0.984	0.880	0.825	0.787	0.770	0.731	0.701
0.85								1.037	0.928	0.825	0.770	0.737	0.710	0.677	0.650
0.80								0.996	0.899	0.784	0.731	0.692	0.670	0.635	0.607
0.75								0.974	0.874	0.753	0.700	0.657	0.637	0.603	0.571
0.70								0.955	0.853	0.728	0.674	0.632	0.614	0.575	0.542
0.65								0.938	0.834	0.708	0.657	0.613	0.588	0.555	0.529
0.60								0.925	0.819	0.689	0.639	0.598	0.572	0.540	0.517
0.55								0.914	0.810	0.681	0.630	0.588	0.561	0.527	0.507
0.50								0.905	0.798	0.672	0.620	0.580	0.553	0.516	0.498
0.45								0.884	0.789	0.664	0.606	0.572	0.546	0.510	0.491
0.40								0.874	0.781	0.659	0.599	0.564	0.540	0.503	0.484
0.30								0.857	0.770	0.652	0.590	0.550	0.529	0.494	0.472
0.20								0.849	0.762	0.649	0.584	0.543	0.518	0.486	0.461
0.10								0.846	0.758	0.648	0.577	0.535	0.505	0.470	0.449
0.00								0.844	0.751	0.647	0.575	0.530	0.492	0.460	0.444

Figure 3. 1977 ROBIN Program: Drag Table

DRAG TABLE (1AUG 1977)

REYNOLDS NUMBER

MACH	1200.	1400.	1600.	1800.	2000.	2200.	2500.	3000.	3500.	4000.	4500.	5000.	5500.	6000.	6500.
4.60	1.069	1.055	1.038												
4.40	1.069	1.055	1.041												
4.20	1.067	1.055	1.043												
4.00	1.065	1.055	1.045												
3.80	1.070	1.058	1.051												
3.60	1.075	1.062	1.055												
3.40	1.084	1.066	1.060												
3.20	1.097	1.084	1.072												
3.00	1.100	1.089	1.075												
2.80	1.105	1.092	1.079												
2.60	1.108	1.094	1.080												
2.50	1.110	1.096	1.081	1.063	1.053	1.046	1.038	1.025	1.015						
2.40	1.111	1.097	1.082	1.064	1.054	1.047	1.039	1.026	1.016						
2.30	1.111	1.096	1.082	1.064	1.052	1.046	1.037	1.025	1.016						
2.20	1.110	1.095	1.081	1.063	1.051	1.044	1.034	1.022	1.012						
2.10	1.109	1.094	1.080	1.063	1.050	1.042	1.032	1.019	1.009						
2.00	1.108	1.093	1.078	1.063	1.048	1.043	1.032	1.020	1.010						
1.95	1.105	1.087	1.074	1.061	1.046	1.039	1.023	1.017	1.007						
1.90	1.103	1.098	1.073	1.058	1.042	1.036	1.023	1.014	1.004						
1.85	1.102	1.086	1.070	1.054	1.039	1.032	1.023	1.010	1.000						
1.80	1.095	1.081	1.066	1.051	1.036	1.028	1.019	1.006	0.996						
1.75	1.095	1.079	1.063	1.047	1.031	1.023	1.014	1.001	0.991						
1.70	1.083	1.066	1.051	1.036	1.027	1.020	1.010	0.997	0.987						
1.65	1.078	1.061	1.046	1.031	1.022	1.017	1.005	0.991	0.981						
1.60	1.073	1.054	1.041	1.034	1.018	1.011	1.000	0.985	0.975						
1.55	1.065	1.049	1.032	1.026	1.010	1.004	0.992	0.978	0.967						
1.50	1.061	1.044	1.027	1.016	1.003	0.992	0.983	0.971	0.960						
1.45	1.053	1.037	1.020	1.011	0.996	0.985	0.977	0.962	0.951						
1.40	1.044	1.027	1.011	1.001	0.989	0.977	0.969	0.953	0.942						
1.35	1.034	1.016	1.000	0.991	0.977	0.967	0.958	0.940	0.929						
1.30	1.021	1.002	0.985	0.980	0.968	0.956	0.945	0.928	0.917						
1.25	1.005	0.987	0.971	0.960	0.948	0.940	0.929	0.910	0.897						
1.20	0.985	0.964	0.954	0.942	0.929	0.924	0.910	0.892	0.878						
1.15	0.968	0.947	0.931	0.919	0.906	0.900	0.888	0.867	0.854						
1.10	0.947	0.936	0.918	0.907	0.892	0.881	0.870	0.855	0.841						
1.05	0.926	0.910	0.895	0.882	0.864	0.854	0.846	0.828	0.813	0.801					
1.00	0.891	0.869	0.857	0.841	0.829	0.818	0.808	0.796	0.781	0.766					
0.95	0.750	0.727	0.715	0.705	0.696	0.686	0.677	0.667	0.656	0.646					
0.90	0.678	0.661	0.652	0.638	0.624	0.620	0.610	0.602	0.593	0.584	0.575				
0.85	0.625	0.611	0.600	0.589	0.579	0.575	0.564	0.558	0.551	0.544	0.537				
0.80	0.584	0.571	0.562	0.551	0.541	0.535	0.530	0.525	0.519	0.513	0.507	0.501	0.500	0.499	
0.75	0.549	0.537	0.526	0.518	0.511	0.505	0.500	0.499	0.494	0.490	0.486	0.481	0.480	0.480	
0.70	0.527	0.515	0.504	0.498	0.488	0.483	0.479	0.473	0.470	0.464	0.458	0.457	0.458	0.459	0.453
0.65	0.515	0.498	0.486	0.481	0.477	0.474	0.469	0.462	0.457	0.451	0.449	0.446	0.447	0.450	0.451
0.60	0.500	0.489	0.479	0.470	0.463	0.460	0.456	0.450	0.448	0.444	0.443	0.442	0.441	0.442	0.443
0.55	0.493	0.480	0.473	0.459	0.452	0.450	0.445	0.443	0.438	0.437	0.432	0.431	0.432	0.433	0.434
0.50	0.484	0.472	0.464	0.452	0.443	0.442	0.436	0.434	0.430	0.429	0.424	0.425	0.426	0.427	0.428
0.45	0.475	0.465	0.456	0.445	0.436	0.435	0.426	0.425	0.421	0.420	0.416	0.420	0.423	0.425	0.426
0.40	0.467	0.457	0.448	0.437	0.429	0.426	0.419	0.416	0.411	0.410	0.408	0.416	0.420	0.423	0.424
0.30	0.454	0.445	0.435	0.428	0.421	0.414	0.407	0.402	0.395	0.394	0.393	0.402	0.407	0.410	0.412
0.20	0.444	0.435	0.424	0.419	0.410	0.405	0.399	0.391	0.384	0.383	0.382	0.391	0.396	0.398	0.400
0.10	0.433	0.425	0.416	0.406	0.398	0.393	0.391	0.384	0.377	0.376	0.376	0.385	0.391	0.393	0.395
0.00	0.430	0.414	0.407	0.396	0.389	0.387	0.384	0.380	0.372	0.371	0.370	0.379	0.386	0.389	0.391

Figure 3 (cont'd). 1977 ROBIN Program: Drag Table

DRAG TABLE (1AUG 1977)

MACH	REYNOLDS NUMBER 7000.	8000.	9000.	10000.	15000.	20000.	25000.	30000.	35000.	40000.
4.60										
4.40										
4.20										
4.00										
3.80										
3.60										
3.40										
3.20										
3.00										
2.80										
2.60										
2.50										
2.40										
2.30										
2.20										
2.10										
2.00										
1.95										
1.90										
1.85										
1.80										
1.75										
1.70										
1.65										
1.60										
1.55										
1.50										
1.45										
1.40										
1.35										
1.30										
1.25										
1.20										
1.15										
1.10										
1.05										
1.00										
0.95										
0.90										
0.85										
0.80										
0.75										
0.70	0.461	0.465	0.469	0.475	0.477	0.485	0.497	0.502	0.511	0.512
0.65	0.454	0.456	0.459	0.463	0.468	0.483	0.487	0.495	0.501	0.505
0.60	0.444	0.447	0.450	0.451	0.462	0.472	0.479	0.485	0.491	0.496
0.55	0.438	0.440	0.442	0.443	0.456	0.464	0.472	0.479	0.485	0.492
0.50	0.431	0.432	0.434	0.435	0.449	0.456	0.465	0.474	0.480	0.496
0.45	0.428	0.431	0.432	0.433	0.444	0.450	0.459	0.468	0.475	0.480
0.40	0.425	0.426	0.427	0.431	0.442	0.448	0.455	0.463	0.468	0.475
0.30	0.414	0.417	0.420	0.429	0.435	0.441	0.445	0.454	0.457	0.465
0.20	0.406	0.408	0.410	0.417	0.428	0.436	0.440	0.449	0.451	0.456
0.10	0.400	0.402	0.404	0.407	0.419	0.431	0.439	0.448	0.450	0.455
0.00	0.394	0.396	0.399	0.402	0.410	0.425	0.438	0.447	0.450	0.455

Figure 3 (cont'd). 1977 ROBIN Program: Drag Table

Comparison of Output

Comparison of a flight reduced with both the 1977 ROBIN and the 1972 HIROBIN program is shown in Figure 4. Note the difference in the initial values of temperature at 97 Km (due to the 1976 Standard Atmosphere), the gradual change in temperature values above 76 Km (removal of supersonic bias), the removal of the Mach 1 spike near 68 Km, and the drag table induced temperature changes below 58 Km.

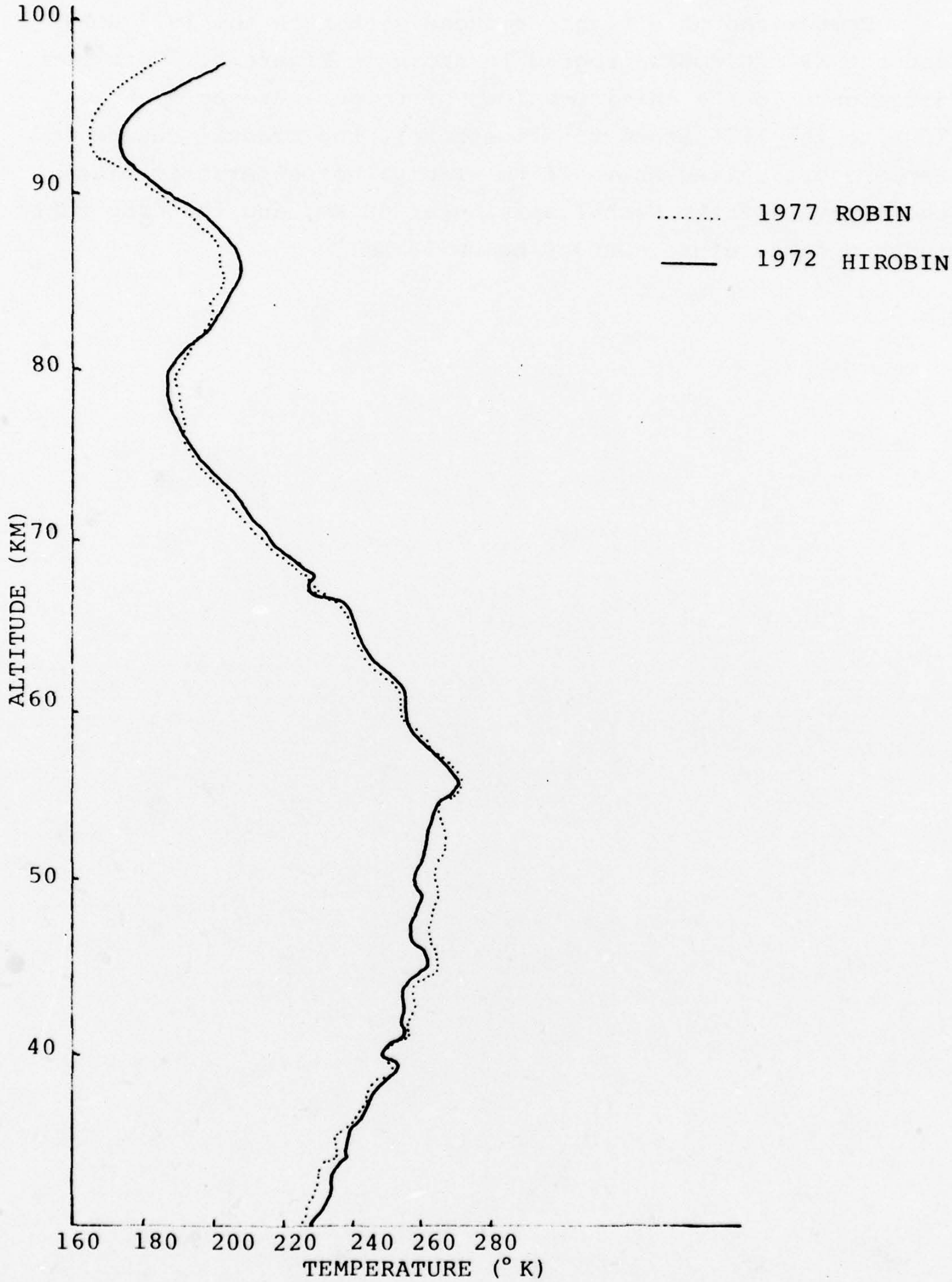

Figure 4. Comparison: 1977 ROBIN vs. 1972 HIROBIN

SECTION 2

PURPOSE AND USE OF PROGRAM

The 1977 ROBIN program is specifically designed for computer reduction of ROBIN flights which attain an apogee of approximately 115 Km, and are tracked by an FPS/16 radar. The program also provides accurate reduction for ROBIN flights attaining other apogees between 65 and 150 Km. If a passive sphere other than the one meter ROBIN (approximately 165 grams) is used, reduction with this program is still possible. There may be times, however, when drag coefficients are not available and thus density, temperature, and pressure cannot be computed. The time of fall test used to determine sphere collapse is not used for spheres with dimensions that differ from the ROBIN.

At each second of flight, the program calculates: altitude, wind components, and direction; density, temperature, and pressure; the RMS noise error in winds, density, temperature, and pressure, and other balloon dynamics.

The following are some of the important features of the 1977 ROBIN program.

(1) The program begins wind and thermodynamic computations when the vertical acceleration ($\ddot{z}$) becomes greater than -8 m/sec^2. For a sphere apogee of 115 Km, this occurs at about 95 Km.

(2) The program computes the RMS noise errors in wind, density, temperature, and pressure. A discussion of other type errors is contained in Section 4 of this manual.

(3) The program determines sphere apogee whenever sufficient tracking data is available.

(4) The program uses two tests as an indication of sphere collapse, a time of fall test, and a density gradient test (λ check).

(5) At the end of the flight the program prints a frequency response table for density and winds. This enables the user to observe what wavelengths have been retained in the output data.

(6) The program provides the following options of output: a) output at each second of flight; b) additional interpolated output at each 200 meters of altitude; and c) output each kilometer only.

(7) Below 60 Km the density smoothing interval expands in such a manner so as to maintain a constant two percent noise error in density.

(8) If spheres other than the ROBIN are used, the reduction can be optimized by changing the smoothing input parameters. However, when using a ROBIN sphere at any escape altitude, it is of fundamental importance that one not change any of the smoothing input.

SECTION 3

OPERATING INSTRUCTIONS

The High Altitude ROBIN program was written using FORTRAN IV. The program was tested on the CDC 6600 computer at Wright-Patterson Air Force Base.

The basic program generally requires two to three minutes to run on the CDC system; however, the run time can be almost twice that if the data tape requires a great deal of editing.

The input to the ROBIN program consists of time, X, Y and Z coordinates. Time is in units of seconds Zulu and the X, Y and Z position coordinates in units of feet. Generally the position coordinates are given with respect to the coordinate system of the firing range. The output from the ROBIN program gives wind measurements with respect to the north and east components. To accomplish the transformation of coordinate systems the positive clockwise angle from geographical north to the positive X-axis of the range coordinate system must be known. The angle is called Z_b and is input to the ROBIN program.

The ROBIN system is divided into two related programs. The first is the tape editing program. It should be noted that this program has not changed since the 1972 version. The main function of this program is to replace bad data points with interpolated data. Its printed output consists of the discarded old points and the added new points. (See Figure 5). The editing routine then writes the edited data on a tape or disk. The data is written in 97 word records with the exception of the first record on a file which contains the flight identification number. The 97 word records begin with a FORTRAN loader word and thereafter contain a 96 word array of data points. An undetermined number of records are written per file since a new file is started every time a gap greater than two seconds occurs in the data. Each time an end of file is written a notice is placed in the printed output.

OLD POINTS	.66131540E+05	.13631032E+06	.36562330E+06	-.44610370E+05
OLD POINTS	.66131640E+05	.13649870E+06	.36573300E+06	-.44693710E+05
OLD POINTS	.66131740E+05	.13667149E+06	.36585229E+06	-.44772160E+05
OLD POINTS	.66131840E+05	.13684326E+06	.36597428E+06	-.44857540E+05
OLD POINTS	.66131935E+05	.13700379E+06	.36610589E+06	-.44924660E+05
OLD POINTS	.66132040E+05	.13712782E+06	.36624848E+06	-.44987160E+05
OLD POINTS	.66132140E+05	.13725722E+06	.36639382E+06	-.45036970E+05
OLD POINTS	.66132240E+05	.13735227E+06	.36654462E+06	-.45068330E+05
NEW POINTS	.66131539E+05	.13628218E+06	.36563858E+06	-.44601243E+05
NEW POINTS	.66131639E+05	.13642779E+06	.36577113E+06	-.44663476E+05
NEW POINTS	.66131739E+05	.13657339E+06	.36590338E+06	-.44725709E+05
NEW POINTS	.66131839E+05	.13671900E+06	.36603562E+06	-.44787942E+05
NEW POINTS	.66131939E+05	.13686461E+06	.36616787E+06	-.44850175E+05
NEW POINTS	.66132039E+05	.13701022E+06	.36630012E+06	-.44912408E+05
NEW POINTS	.66132139E+05	.13715583E+06	.36643237E+06	-.44974642E+05
NEW POINTS	.66132239E+05	.13730144E+06	.36656462E+06	-.45036875E+05
OLD POINTS	.66138740E+05	.14180273E+06	.37686530E+06	-.47041170E+05
OLD POINTS	.66138840E+05	.14201162E+06	.37695136E+06	-.47117850E+05
OLD POINTS	.66138939E+05	.14222596E+06	.37704566E+06	-.47188960E+05
OLD POINTS	.66139040E+05	.14243389E+06	.37712868E+06	-.47265650E+05
OLD POINTS	.66139140E+05	.14259045E+06	.37723320E+06	-.47325190E+05
OLD POINTS	.66139240E+05	.14272872E+06	.37734765E+06	-.47386150E+05
OLD POINTS	.66139340E+05	.14285311E+06	.37747206E+06	-.47435170E+05
OLD POINTS	.66139439E+05	.14297311E+06	.37759086E+06	-.47430540E+05
OLD POINTS	.66139540E+05	.14309666E+06	.37771240E+06	-.47538900E+05
OLD POINTS	.66139640E+05	.14318262E+06	.37784002E+06	-.47575070E+05
OLD POINTS	.66139740E+05	.14326629E+06	.37796763E+06	-.47618190E+05
NEW POINTS	.66138740E+05	.14174846E+06	.37687625E+06	-.47031848E+05
NEW POINTS	.66138840E+05	.14189112E+06	.37698889E+06	-.47088097E+05
NEW POINTS	.66138940E+05	.14203377E+06	.37710153E+06	-.47144345E+05

Figure 5. ROBIN Position Edit of Tape 1877

DATA INPUT TO ROBIN EDITING PROGRAM

Card 1

Column	Variable	Description
1-10	ID	Flight Identification number
11-15	IX	Output unit
15-20	IY	Input Unit
21-30	XTOL	The X tolerance = 150.0 ft.
31-40	YTOL	The Y tolerance = 150.0 ft.
41-50	ZTOL1	The Z tolerance at or above 200000.0 ft. = 360.0 ft.
51-60	ZTOL2	The Z tolerance below 200000.0 ft = 200.0 ft.
61-70	ALT	Read past ascent data to ALT = 300000.0 ft. (for high apogee Robin; adjust if apogee is known to be lower)

The main ROBIN program uses the edited data to compute the desired meteorological parameters. The methods used to compute the parameters are discussed in References 2, 4, and 5. Once the parameters are computed they are printed. The ROBIN program provides the options of printing only the actual data, printing the actual data and data interpolated at every 200 meters of descent, or printing interpolated data every kilometer. Figures 6, 7, and 8 illustrate these alternatives.

DATA INPUT TO ROBIN PROGRAM

Card 1

Column	Variable	Description
1-5	NXY1	Number of points for wind velocity fit = 51.
6-10	NXY2	Number of points for wind acceleration fit = 35.
11-15	NZ1	Number of points for density velocity fit = 19.
16-20	NZ2	Number of points for density acceleration fit = 21
21-25	IDEGX1	Degreee of fit for wind velocity=3
26-30	IDEGX2	Degree of fit for wind acceleration = 3.
31-35	IDEGZ1	Degree of fit for density velocity = 1.
36-40	IDEGZ2	Degree of fit for density acceleration = 3.

Card 2

1-80	ANAME	Description title of job.

Card 3

1-10	ID	Flight number.
11-12	IX	Input tape (disk) unit.
13-14	IY	Output tape (disk) unit.
15-20	ALA	Latitude of launch site
21-27	HMSL	Height above mean sea level of launch site (meters).
28-33	ZB	Angle of X axis from north (degrees).

REDUCTION OF WSMR TAPE 1877

	XY-VEL	XY-ACC	Z-VEL	Z-ACC
= PTS. FIT	51	35	19	21
DEGREE FIT	3	3	1	3

ID UNIT	ALA	GS	RG	HMSL	ZB	AMS DIA	INT
1877 9 6	32.46	-9.780505	6371229.3	1220.0	0.0	.1614 1.00000	0

TIME ZULU	ALT METERS	EWIND M/S	NWIND M/S	SPEED KNOTS	DIR DEG	PRESS MB	T K	DENSITY GP/M3	Z VEL M/S	Z ACC M/S2	MACH	REYNL	CD	***R.M.S. NOISE ERROR IN*** DENS *****PERCENT	PRES	TEMP *****	EW M/S	NW M/S
						BALLOON APOGEE = 127 KM.												
18.24.23	98802	90.0	-169.0	371.97	331	.00039	193	.00070	-715.98	-7.83	3.06	47	1.535	9.4	.6	9.4	25.9	33.2
18.24.24	98095	92.9	-158.4	356.78	329	.00044	194	.00078	-726.58	-7.63	3.05	53	1.517	8.5	1.2	9.6	23.7	30.0
18.24.25	97349	95.5	-140.7	330.41	325	.00049	198	.00087	-734.48	-7.41	3.02	58	1.505	7.8	1.4	7.9	21.6	27.0
18.24.26	96637	94.3	-119.6	295.92	321	.00056	198	.00098	-741.34	-7.17	3.00	65	1.492	7.1	1.5	7.2	19.6	24.2
18.24.27	95878	92.7	-94.8	257.50	315	.00063	202	.00109	-748.84	-6.92	2.95	71	1.482	6.5	1.5	6.7	17.6	21.4
18.24.28	95133	91.4	-68.3	221.60	306	.00071	205	.00121	-755.70	-6.64	2.92	78	1.470	5.9	1.5	6.1	15.8	18.9
18.24.29	94378	86.8	-43.0	188.27	296	.00080	205	.00136	-761.01	-6.31	2.90	88	1.450	5.4	1.5	5.6	14.0	16.5
18.24.30	93605	81.8	-20.5	163.75	284	.00091	203	.00156	-767.15	-5.90	2.90	101	1.420	4.8	1.5	5.0	12.3	14.4
18.24.31	92837	76.2	-1.4	148.02	271	.00103	201	.00178	-772.47	-5.43	2.90	116	1.400	4.3	1.4	4.5	10.8	12.5
18.24.32	92081	69.6	14.3	138.09	258	.00117	199	.00205	-778.41	-4.86	2.92	136	1.377	3.8	1.3	4.0	9.4	10.8
18.24.33	91300	62.0	26.7	131.18	246	.00134	195	.00238	-782.98	-4.18	2.95	161	1.349	3.4	1.2	3.6	8.2	9.3
18.24.34	90525	56.0	37.3	130.73	236	.00153	191	.00279	-787.24	-3.38	2.98	193	1.318	2.9	1.1	3.2	7.2	8.1
18.24.35	89735	48.9	45.2	129.31	227	.00176	186	.00329	-790.16	-2.47	3.01	231	1.292	2.6	1.1	2.8	6.3	7.0
18.24.36	88939	39.6	50.3	124.39	218	.00203	182	.00388	-792.07	-1.33	3.03	275	1.267	2.2	1.0	2.4	5.5	6.1
18.24.37	88158	30.2	53.9	120.10	209	.00235	179	.00457	-793.12	-.09	3.05	327	1.245	2.0	.9	2.2	4.9	5.3
18.24.38	87350	21.0	56.3	116.77	200	.00274	177	.00538	-793.01	1.29	3.05	380	1.229	1.7	.8	1.9	4.3	4.7
18.24.39	86570	10.9	57.7	114.11	190	.00317	174	.00634	-789.94	2.79	3.04	445	1.211	1.5	.7	1.7	3.8	4.1
18.24.40	85769	1.0	58.4	113.53	180	.00370	174	.00736	-786.79	4.34	3.01	507	1.194	1.4	.7	1.5	3.4	3.7
18.24.41	84975	-9.3	58.6	115.18	171	.00429	177	.00841	-781.80	5.94	2.96	565	1.185	1.2	.6	1.4	3.1	3.3
18.24.42	84208	-19.2	58.8	118.71	161	.00495	180	.00954	-775.32	7.51	2.91	622	1.178	1.1	.5	1.3	2.8	3.0
18.24.43	83437	-27.8	57.0	123.16	154	.00569	183	.01082	-766.72	9.11	2.84	680	1.171	1.0	.5	1.2	2.6	2.7
18.24.44	82658	-36.3	55.5	128.83	146	.00655	186	.01223	-756.53	10.71	2.78	741	1.163	1.0	.5	1.1	2.4	2.5
18.24.45	81917	-43.3	53.5	133.76	140	.00747	189	.01376	-745.27	12.30	2.72	809	1.153	.9	.4	1.0	2.2	2.2
18.24.46	81178	-48.5	51.4	137.22	136	.00850	191	.01545	-731.88	13.82	2.65	880	1.142	.9	.4	.9	2.0	2.1
18.24.47	80454	-53.5	49.0	140.98	132	.00963	194	.01723	-717.66	15.24	2.58	951	1.131	.8	.4	.9	1.9	1.9
18.24.48	79756	-57.1	46.5	143.06	129	.01084	197	.01913	-701.97	16.53	2.51	1019	1.122	.8	.3	.9	1.8	1.8
18.24.49	79035	-59.0	43.9	142.78	126	.01224	201	.02120	-685.00	17.71	2.42	1074	1.119	.8	.3	.8	1.7	1.7
18.24.50	78375	-60.0	41.1	141.38	124	.01365	203	.02340	-666.66	18.70	2.34	1134	1.116	.8	.3	.8	1.6	1.6
18.24.51	77706	-60.4	38.1	138.82	122	.01523	206	.02572	-647.56	19.51	2.26	1190	1.111	.7	.3	.8	1.5	1.5
18.24.52	77081	-59.1	35.3	133.77	120	.01684	207	.02825	-626.72	20.13	2.18	1255	1.106	.7	.3	.8	1.4	1.4
18.24.53	76466	-57.1	32.5	127.60	119	.01859	209	.03093	-605.57	20.58	2.10	1319	1.100	.7	.2	.8	1.4	1.4
18.24.54	75870	-54.1	30.0	120.11	118	.02044	211	.03362	-585.15	20.86	2.02	1372	1.095	.7	.2	.8	1.3	1.3
18.24.55	75292	-50.7	27.3	111.88	118	.02238	213	.03654	-564.67	20.96	1.95	1433	1.085	.7	.2	.8	1.3	1.3
18.24.56	74755	-47.0	24.6	103.16	117	.02434	214	.03949	-543.86	20.91	1.87	1489	1.080	.8	.2	.8	1.3	1.2
18.24.57	74210	-42.8	22.2	93.60	117	.02648	216	.04254	-523.49	20.67	1.80	1539	1.071	.6	.2	.8	1.2	1.2
18.24.58	73709	-38.4	19.7	83.72	117	.02859	216	.04592	-502.48	20.29	1.73	1611	1.057	.8	.2	.8	1.2	1.2
18.24.59	73203	-34.1	17.4	74.42	117	.03090	217	.04954	-482.50	19.79	1.66	1676	1.042	.8	.2	.8	1.2	1.1
18.25. 0	72748	-29.4	15.5	64.47	117	.03314	218	.05294	-463.40	19.16	1.59	1711	1.036	.8	.2	.9	1.2	1.1

Figure 6. University of Dayton 1977 ROBIN Program
(Actual Data)

REDUCTION OF WSMR TAPE 1877

	XY-VEL	XY-ACC	Z-VEL	Z-ACC
= PTS. FIT	51	35	19	21
DEGREE FIT	3	3	1	3

IO	UNIT	ALA	GS	RG	HMSL	ZB	AMS	DIA	INT
1877	8 6	32.46	-9.780505	6371229.3	1220.0	0.0	.1614	1.00000	1

BALLOON APOGEE = 127 KM.

TIME ZULU	ALT METERS	EWIND M/S	NWIND M/S	SPEED KNOTS	DIR DEG	PRESS MB	T K	DENSITY GR/M3	Z VEL M/S	Z ACC M/S2	MACH	REYNL	CD	***R.M.S. NOISE ERROR IN*** DENS *****PERCENT	PRES	TEMP*****	EW M/S	NW M/S
18.24.23	98802	90.0	-169.0	371.97	331	.00039	193	.00070	-718.98	-7.83	3.06	47	1.535	9.4	.6	9.4	25.9	33.2
	98800	90.0	-169.0	371.93	331	.00039	193	.00070	-719.00	-7.83	3.06	47	1.535	9.4	.6	9.4	25.9	33.2
	98600	90.8	-166.0	367.62	331	.00040	193	.00072	-721.15	-7.77	3.06	49	1.530	9.2	.7	9.2	25.3	32.3
	98400	91.7	-163.0	363.32	330	.00041	193	.00074	-723.31	-7.71	3.06	51	1.524	8.9	.9	9.0	24.6	31.4
	98200	92.5	-160.0	359.02	329	.00043	194	.00077	-725.46	-7.66	3.05	52	1.519	8.7	1.1	8.7	24.0	30.5
18.24.24	98095	92.9	-158.4	356.78	329	.00044	194	.00078	-726.58	-7.63	3.05	53	1.517	8.5	1.2	8.6	23.7	30.0
	98000	93.2	-156.2	353.39	329	.00044	194	.00079	-727.60	-7.60	3.05	54	1.515	8.4	1.2	8.5	23.4	29.6
	97800	94.0	-151.4	346.32	328	.00046	195	.00081	-729.71	-7.54	3.04	55	1.512	8.2	1.3	8.3	22.9	28.8
	97600	94.7	-146.7	339.26	327	.00047	196	.00084	-731.83	-7.48	3.03	57	1.509	8.0	1.3	8.1	22.3	28.0
	97400	95.4	-141.9	332.19	326	.00049	197	.00086	-733.95	-7.43	3.02	58	1.506	7.8	1.4	8.0	21.7	27.2
18.24.25	97349	95.5	-140.7	330.41	325	.00049	198	.00087	-734.48	-7.41	3.02	59	1.505	7.8	1.4	7.9	21.6	27.0
	97200	95.3	-136.3	323.17	325	.00051	198	.00089	-735.92	-7.36	3.02	60	1.502	7.6	1.4	7.8	21.2	26.4
	97000	94.9	-130.4	313.49	323	.00052	198	.00092	-737.85	-7.29	3.01	62	1.499	7.4	1.4	7.6	20.5	25.6
	96800	94.6	-124.5	303.81	322	.00054	198	.00095	-739.77	-7.22	3.01	64	1.495	7.2	1.5	7.4	20.0	24.9
18.24.26	96637	94.3	-119.6	295.92	321	.00056	198	.00098	-741.34	-7.17	3.00	65	1.492	7.1	1.5	7.2	19.6	24.2
	96600	94.2	-118.4	234.04	321	.00056	198	.00098	-741.71	-7.16	3.00	65	1.492	7.0	1.5	7.2	19.5	24.0
	96400	93.8	-111.9	283.91	320	.00058	199	.00101	-743.68	-7.09	2.99	67	1.489	6.9	1.5	7.0	19.0	23.3
	96200	93.4	-105.3	273.78	318	.00060	200	.00104	-745.66	-7.02	2.97	68	1.487	6.7	1.5	6.9	18.5	22.6
	96000	92.9	-98.8	263.66	316	.00062	201	.00107	-747.64	-6.96	2.96	70	1.484	6.6	1.5	6.7	17.9	21.9
18.24.27	95878	92.7	-94.8	257.50	315	.00063	202	.00109	-748.84	-6.92	2.95	71	1.482	6.5	1.5	6.7	17.6	21.4
	95800	92.5	-92.0	253.72	314	.00064	202	.00110	-749.56	-6.89	2.95	72	1.481	6.4	1.5	6.6	17.4	21.2
	95600	92.2	-84.9	244.07	312	.00066	203	.00113	-751.40	-6.81	2.94	74	1.478	6.3	1.5	6.4	16.9	20.5
	95400	91.8	-77.8	234.43	310	.00068	204	.00117	-753.25	-6.74	2.93	75	1.475	6.1	1.5	6.3	16.4	19.8
	95200	91.5	-70.6	224.79	307	.00071	204	.00120	-755.09	-6.66	2.92	77	1.471	6.0	1.5	6.2	15.9	19.1
18.24.28	95133	91.4	-68.3	221.60	306	.00071	205	.00121	-755.70	-6.64	2.92	78	1.470	5.9	1.5	6.1	15.8	18.9
	95000	90.6	-63.8	215.69	305	.00073	205	.00124	-756.64	-6.57	2.91	80	1.467	5.8	1.5	6.0	15.5	18.5
	94800	89.4	-57.1	206.86	302	.00075	205	.00127	-758.05	-6.49	2.91	82	1.461	5.7	1.5	5.9	15.0	17.9
	94600	88.2	-50.4	196.04	299	.00078	205	.00131	-759.45	-6.40	2.90	85	1.456	5.5	1.5	5.7	14.5	17.2
	94400	87.0	-43.7	189.21	296	.00080	205	.00136	-760.86	-6.32	2.90	87	1.450	5.4	1.5	5.6	14.1	16.6
18.24.29	94378	86.8	-43.0	188.27	296	.00080	205	.00136	-761.01	-6.31	2.90	88	1.450	5.4	1.5	5.6	14.0	16.5
	94200	85.7	-37.8	182.60	293	.00083	205	.00140	-762.43	-6.21	2.90	91	1.443	5.2	1.5	5.4	13.6	16.0
	94000	84.4	-32.0	176.26	290	.00086	204	.00146	-764.01	-6.11	2.90	94	1.435	5.1	1.5	5.3	13.2	15.5
	93800	83.1	-26.1	169.92	287	.00088	203	.00151	-765.60	-6.00	2.90	98	1.427	4.9	1.5	5.2	12.8	14.9
18.24.30	93605	81.8	-20.5	163.75	284	.00091	203	.00156	-767.15	-5.90	2.90	101	1.420	4.8	1.5	5.0	12.3	14.4

Figure 7. University of Dayton 1977 ROBIN Program (Data Interpolated every 200 meters)

REDUCTION OF WSMR TAPE 1877 (TODAY IS 12JUNE78)

	XY-VEL	XY-ACC	Z-VEL	Z-ACC
= PTS. FIT	51	35	19	21
DEGREE FIT	3	3	1	3

ID	UNIT	ALA	GS	EG	HMSL	ZB	AMS	DIA	INT
7877	8 6	32.46	-9.780505	6371229.3	1220.0	0.0	.1614	1.00000	2

BALLOON APOGEE = 127 KM.

TIME ZULU	ALT METERS	EWIND M/S	NWIND M/S	SPEED KNOTS	DIR DEG	PRESS MB	T K	DENSITY GM/M3	Z VEL M/S	Z ACC M/S2	MACH	REYNL	CD	***R.M.S. NOISE ERROR IN*** DENS *****PERCENT	PRES	TEMP*****	EW M/S	NW M/S
	98000	33.2	-156.2	353.32	329	.00044	194	.00079	-727.60	-7.60	3.05	54	1.515	8.4	1.2	8.5	23.4	29.6
	97000	34.3	-130.4	313.49	323	.00052	198	.00092	-737.35	-7.29	3.01	62	1.499	7.4	1.4	7.6	20.6	25.6
	96000	92.9	-98.8	263.66	316	.00062	201	.00107	-747.64	-6.96	2.96	70	1.484	6.6	1.5	6.7	17.9	21.9
	95000	90.6	-63.8	215.69	305	.00073	205	.00124	-756.64	-6.58	2.91	80	1.467	5.6	1.5	6.0	15.5	18.5
	94000	84.4	-32.0	176.26	290	.00086	204	.00146	-764.01	-6.11	2.90	94	1.435	5.1	1.5	5.3	13.2	15.5
	93000	77.4	-5.5	151.35	274	.00101	202	.00173	-771.34	-5.53	2.90	113	1.404	4.4	1.4	4.6	11.1	12.9
	92000	68.8	15.6	137.37	257	.00119	198	.00205	-776.99	-4.79	2.92	138	1.374	3.8	1.3	4.0	9.3	10.6
	91000	59.7	30.8	131.00	242	.00141	193	.00253	-784.63	-3.87	2.96	173	1.337	3.2	1.2	3.4	7.8	8.8
	90000	51.3	42.6	129.73	230	.00168	188	.00311	-769.19	-2.74	3.00	219	1.301	2.7	1.1	2.9	6.6	7.3
	89000	40.3	49.9	124.77	218	.00201	183	.00383	-751.93	-1.41	3.03	272	1.269	2.3	1.0	2.5	5.6	6.2
	88000	28.4	54.4	119.45	207	.00242	178	.00472	-733.10	.18	3.05	337	1.242	1.9	.9	2.1	4.8	5.2
	87000	16.5	57.0	115.57	196	.00293	175	.00579	-751.63	1.96	3.04	410	1.221	1.6	.8	1.8	4.1	4.4
	86000	3.9	58.2	113.70	183	.00354	174	.00705	-787.70	3.69	3.02	493	1.199	1.4	.7	1.6	3.6	3.8
	85000	-9.0	58.6	115.13	171	.00427	177	.00837	-781.35	5.89	2.96	564	1.186	1.2	.6	1.4	3.1	3.3
	84000	-21.5	57.8	119.92	159	.00514	181	.00987	-772.99	7.95	2.33	637	1.176	1.1	.5	1.2	2.7	2.9
	83000	-32.5	56.2	126.35	149	.00616	185	.01159	-760.99	10.01	2.81	714	1.167	1.0	.5	1.1	2.5	2.6
	82000	-42.6	53.7	133.21	141	.00736	188	.01358	-746.53	12.12	2.72	801	1.154	.9	.4	1.0	2.2	2.3
	81000	-49.7	50.8	138.15	135	.00876	192	.01587	-728.37	14.17	2.63	897	1.139	.9	.4	.9	2.0	2.0
	80000	-55.9	47.4	142.33	130	.01040	196	.01844	-707.44	16.08	2.54	995	1.125	.8	.3	.9	1.8	1.8
	79000	-59.0	43.8	142.71	126	.01231	201	.02131	-684.02	17.76	2.42	1077	1.119	.8	.3	.8	1.7	1.7
	78000	-60.3	39.5	139.94	123	.01451	204	.02468	-655.35	19.15	2.30	1166	1.113	.7	.3	.8	1.5	1.5
	77000	-58.9	34.9	132.95	120	.01706	207	.02859	-623.31	20.19	2.17	1264	1.105	.7	.3	.8	1.4	1.4
	76000	-54.7	30.5	121.74	119	.02002	211	.03302	-583.59	20.80	2.04	1360	1.096	.7	.2	.8	1.4	1.3
	75000	-48.7	25.8	107.13	117	.02343	214	.03812	-553.31	20.93	1.90	1463	1.082	.7	.2	.8	1.3	1.2
	74000	-40.9	21.1	89.44	117	.02735	216	.04393	-514.65	20.51	1.77	1569	1.065	.8	.2	.8	1.2	1.2
	73000	-32.0	16.6	69.97	117	.03188	217	.05103	-473.97	19.51	1.63	1692	1.039	.8	.2	.8	1.2	1.1
	72000	-23.2	12.9	51.53	119	.03716	217	.05959	-431.07	17.87	1.49	1602	1.015	.9	.2	.9	1.1	1.1
	71000	-18.3	10.4	40.85	119	.04331	218	.06898	-390.03	15.65	1.34	1682	.983	1.0	.2	1.0	1.1	1.0

BALLOON STILL INFLATED AT 70 KM.

TIME ZULU	ALT METERS	EWIND M/S	NWIND M/S	SPEED KNOTS	DIR DEG	PRESS MB	T K	DENSITY GM/M3	Z VEL M/S	Z ACC M/S2	MACH	REYNL	CD	DENS	PRES	TEMP	EW M/S	NW M/S
	70000	-20.3	9.5	43.57	115	.05038	220	.07974	-351.52	12.94	1.20	1964	.933	1.1	.2	1.1	1.1	1.0
	69000	-33.3	10.3	67.64	107	.05860	217	.09365	-317.02	10.23	1.09	2024	.877	1.2	.2	1.2	1.2	1.0
	68000	-52.9	11.2	104.73	101	.06828	213	.11145	-287.17	7.54	.99	2226	.778	1.4	.2	1.4	1.2	1.1
	67000	-67.5	11.2	132.37	99	.08036	210	.13283	-263.15	4.94	.92	2597	.640	1.6	.2	1.6	1.3	1.1
	66000	-66.8	11.2	131.64	99	.09386	213	.15310	-248.35	3.53	.86	2725	.569	1.7	.2	1.7	1.3	1.1
	65000	-56.2	12.3	111.71	102	.11000	209	.18310	-234.65	3.42	.81	3125	.532	1.8	.2	1.8	1.3	1.1
	64000	-48.1	11.1	95.93	102	.12934	205	.21645	-219.16	3.01	.76	3464	.500	1.9	.2	1.9	1.3	1.1
	63000	-44.2	4.8	86.41	96	.15165	214	.24619	-206.15	2.54	.71	3644	.473	1.9	.2	2.0	1.2	1.0

Figure 8. University of Dayton 1977 ROBIN Program (Data Interpolated Every Km)

34-40	AMS	Mass of Balloon (kilograms).
41-48	DIA	Diameter of balloon (meters).
49-51	Interp	Switch Interp = 0 no interpolation Interp = 1 interpolation every 200 meters. Interp = 2 print at every kilometer only.

The deck setup is shown in Figure 9.

Input and Output Units by ROBIN System

Units five and six are the standard FORTRAN input and output units.

Units	Mode	Block Size	Usage
Edit Program			
8	Binary	97	Edited input tape (or disk output for edit program.
1	Binary	97	Input tape
ROBIN Program			
8	Binary	97	Edit input tape (or disk). Same as unit 8 in edit program.
10	Binary	6	Output tape(or disk) for plot program.

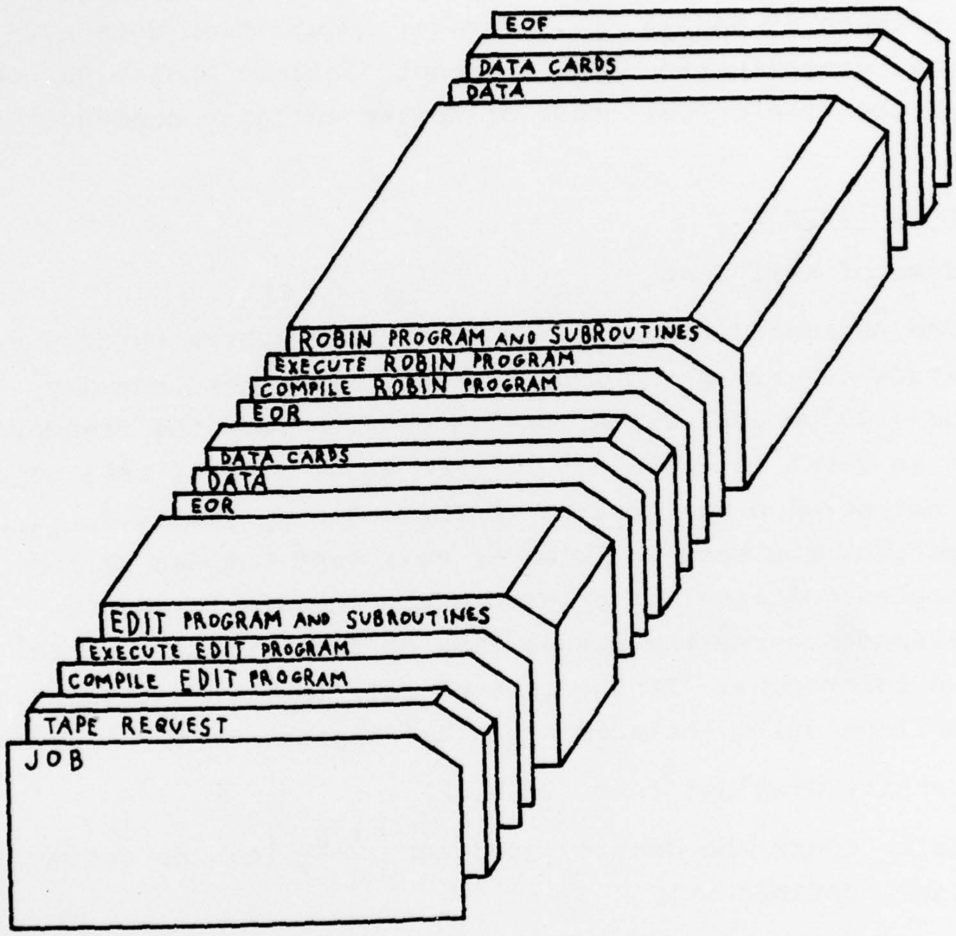

Figure 9. Typical Deck Setup

SECTION 4

DATA INTERPRETATION

Apogee Determination

Sphere apogee can be determined if the radar acquires track before the downward velocity of the sphere exceeds 150 m/sec. The sphere apogee must be determined in order to use the time of fall test between 80 and 55 Km. If radar acquisition does not permit apogee determination, the printout "Balloon Apogee Unknown" appears and the time of fall test of sphere collapse commences at 55 Km.

Sphere Collapse

a) Time of Fall Test

The estimated time of fall of a ROBIN sphere through 5 and 10 Km altitude layers in the 1962 Standard Atmosphere density ($\rho_{"62"}$) and $\pm$ 20 percent variations in density from the Standard Atmosphere is given in Table 1. If the actual time of fall of a sphere is not between that estimated for a $0.8\rho_{"62"}$ and $1.2\rho_{"62"}$ density profile, the message "Time of Fall Test Between XX and XX Km indicates Collapse" is printed out. Invariably when a sphere collapse occurs, the actual time of fall greatly exceeds the imposed tolerances. If the time of fall test is satisfied, the message "Balloon Still Inflated at XX Km" appears in the printout.

b) Density Gradient Test (λ Check)

Below 60 Km the density gradient $\left(\frac{1}{\rho}\frac{d\rho}{dz}\right)$ can be estimated by computing λ defined as:

$$\lambda = \frac{2}{z_2 - z_1}\left(\text{Log}(\dot{z}_2) - \text{Log}(\dot{z}_1)\right) \simeq \frac{1}{\rho}\frac{d\rho}{dz}$$

The expected value of λ between 30 and 60 Km, obtained from the "62" Standard Atmosphere, is $\lambda = .00014$. To allow for density perturbations in the real atmosphere, a tolerance of .00005 is allowed. In addition to allowing a tolerance in λ for real density perturbation, a tolerance must also be allowed for the inaccuracies

ALTITUDE (KM)

Apogee (km)		80-70	70-60	60-55	55-50	50-45	45-40	40-35	35-30
150 km	$.8\rho_{62}$	18	43	32	44	59	84	124	198
	ρ_{62}	21	49	37	51	69	96	142	218
	$1.2\rho_{62}$	24	52	39	54	74	106	156	232
140 km	$.8\rho_{62}$	19	Same for all Apogees						
	ρ_{62}	22							
	$1.2\rho_{62}$	25							
125 km	$.8\rho_{62}$	21							
	ρ_{62}	25							
	$1.\rho_{62}$	27							
115 km	$.8\rho_{62}$	22							
	ρ_{62}	26							
	$1.2\rho_{62}$	28							
100 km	$.8\rho_{62}$	26							
	ρ_{62}	30							
	$1.2\rho_{62}$	32							
80 km	$.8\rho_{62}$	-	44						
	ρ_{62}	-	49						
	$1.2\rho_{62}$	-	52						
70 km	$.8\rho_{62}$	-	-	33	44	59	84	124	198
	ρ_{62}	-	-	37	51	69	96	142	218
	$1.2\rho_{62}$	-	-	39	54	74	106	156	232

Table 1. Time of Fall in Seconds through Standard Atmosphere and + 20% Deviations from Standard for Sphere Apogees Between 70 and 150 Km

of the parameters used to compute λ. For a two percent noise error in density, the 3σ noise tolerance for λ is $3\sigma_\lambda = \frac{.08484}{\Delta z}$.

The check is summarized as follows:

Expected value of λ = .00014;

Tolerance for variation in density is $\pm$ .00005; and

3σ noise tolerance is $\pm \frac{.08484}{\Delta z}$, Δz is in units of meters.

A sphere is considered inflated if:

$$.00014 - \left[(.00005)^2 + \left(\frac{.08484}{\Delta z}\right)^2\right]^{1/2} \leq \lambda \leq .00014 + \left[(.00005)^2 + \left(\frac{.08484}{\Delta z}\right)^2\right]^{1/2}$$

If the λ check fails, the message "Density Gradient Exceeds Nominal Value" appears in the printout. The λ check is the secondary balloon collapse check and should be used in conjunction with the time of fall tests. The λ check is a sensitive check and occasionally can be tripped by a vertical wind or density anomaly not connected with sphere collapse. In this case the error message will appear only sparingly and the time of fall test will validate proper balloon inflation. When sphere collapse is indicated by the time of fall test over say a 5 Km interval, the λ check will often pinpoint the actual collapse within an accuracy of 1 Km. If a non-ROBIN sphere is used, the λ check serves as the only indication of sphere collapse.

Density Errors

Sources which can produce significant density errors are as follows.

a) Random error in density due to radar noise.

b) Bias error in density introduced by smoothing function.

c) Error in initial guess at temperature.

d) Drag coefficient errors.

e) Vertical winds.

a) Noise Error in Density

The random error in density is that error resulting from noise in the radar signal. The magnitude of this error for a nominal 115 Km apogee and the 19-21 linear cubic smoothing (expanding to 51-21) used on density is given by the first line of Table 2. The two percent noise error in density is maintained below 60 Km by gradually expanding the smoothing interval from 19-21 to 51-21 linear cubic. The RMS noise error in density is computed in the ROBIN program by assuming an RMS error of 0.15 mil in azimuth and elevation angles and 6 meters in slant range. The RMS error value printed out by the program may differ slightly from that given in Table 2 due to a different sphere apogee and trajectory.

b) Bias Errors in Density

A bias error is introduced into density when the smoothing function does not fit true perturbations in the position coordinates. Incorporated into the 1977 program is a bias removal technique that will remove the bias error resulting from a sphere flight through the 1976 Standard Atmosphere. Since an actual atmosphere will differ somewhat from the "76" Standard, not all of the bias will be removed. The second row of Table 2 shows typical values of the unremoved bias based upon simulated flights through other atmospheres.

c) Initial Guess of T_o

A guess of the temperature at the initial altitude of thermodynamic computations (approximately 95 Km) is required. This temperature error produces a density error in succeeding computation which decreases with altitude. The percent error in density produced by a ten percent error in the initial temperature at 95 Km is given by Table 2. The effect of this error becomes negligible after 5 Km of flight.

d) Drag Coefficient Errors

Errors in the drag coefficient effect density accuracy in two ways: a) drag coefficient error directly produces density errors since C_D is in the formula used to compute density; and b) an

	95	90	85	80	75	70	65	60	55	50	40	30
Noise Error	8	4	1	1	1	1	2	2	2	2	2	2
Unremoved Bias Error	1	1	1	1	1	1	1	1	less than 1/2%			
Error due to 10% error in T_o	3	1	less than 1/2%									
Error from C_D	2	2	1	1	1	1	1	1	1	1	1	1
Error from 1 m/sec vertical wind — wavelength (Km) 2									.7	1	4	9
wavelength (Km) 5	less than 1/2%						7	1	1	2	5	10
wavelength (Km) 10						.6	1	1	1.	2	5	10

Table 2. Percent Error in Density from Various Sources for Sphere with Apogee 115 Km.

error in C_D produces a density error which in turn produces an error in Reynolds and Mach numbers so that the Reynolds and Mach numbers used to determine C_D puts one in the wrong region of the drag table.

The drag table used in the 1977 ROBIN program is based upon Bailey and Hiatt's (Reference 1) ballistic sphere measurements with revision in the subsonic region recommended by the Datasonde-sphere comparisons study of Engler and Luers (Reference 2). Bailey and Hiatt quote a maximum error of two percent throughout the observational range. With the revisions due to comparison with other sensors, it is believed that the drag table accuracy in some regions is greater than two percent. Table 2 gives the best estimate of density errors resulting from inaccuracies in the drag table.

e) Vertical Winds

In order to compute density from a passive sphere, one must assume no vertical winds. Actual vertical winds will produce fictitious density perturbations. The percent error in density produced by a 1 m/sec vertical wind of wavelength 2 to 10 Km is given in Table 2. To obtain the percent density error produced by vertical winds of some other magnitude, say X m/sec, the entries in Table 2 are multiplied by X.

Pressure Errors

Pressure is computed in the ROBIN program by an integration of density. Hence errors in pressure can result from all sources of density error.

a) Noise Error in Pressure

The percent error in pressure resulting from the noise errors in density is given in Table 3. This error is printed in the computer output. It may differ slightly from the values given in Table 3 due to a different sphere apogee and trajectory.

b) Bias Errors in Pressure

The percent bias error in pressure resulting from the unremoved bias in density is given by line 2 of Table 3.

	95	90	85	80	75	70	65	60	55	50	40	30
Noise Error	2	1	less than 1/2%									
Unremoved Bias Error	1	1	1	1	1	1	less than 1/2%					
Error due to 10% error in T_o	5	2	less than 1/2%									

Table 3. Percent Error in Pressure for Sphere with Apogee 115 Km

The bias in pressure due to a ten percent error in the initial temperature is given by line 3 of Table 3.

Error in pressure due to drag coefficient errors or vertical winds cannot be directly calculated. Since pressure is computed by integrating density, the error in pressure resulting from C_D errors depends upon the entire C_D error profile. If C_D errors are biased, say all positive, the effect on density error will be greater than if the same magnitude C_D errors are randomly positive and negative. Since the type C_D error profile is beyond the present state of knowledge, pressure errors resulting from C_D errors cannot be estimated.

The effect of vertical winds on pressure accuracy depends upon the vertical wind profile of the entire atmosphere. Since this information is also beyond present knowledge, the pressure error produced by vertical winds cannot be estimated.

Temperature Errors

Temperature is computed by the gas law from density and pressure. Hence, the sources of temperature errors are all the sources of density errors. The relationship between temperature, density, and pressure errors is indicated by the formula:

$$\frac{dT}{T} = \frac{dp}{p} - \frac{d\rho}{\rho} \quad . \tag{1}$$

Hence, the temperature error profile is obtained from the density error profile and the pressure error profile produced by the density error profile.

a) Noise Error in Temperature

The error in temperature due to the noise error in density is given by Table 4, line 1. The noise error in temperature appears in the computer output of the program. The unremoved bias error in the density profile due to smoothing produces a bias in temperature. The second line in Table 4 shows this error.

The effect of a ten percent error in the initial temperature on succeeding temperature calculations is also given

	95	90	85	80	75	70	65	60	55	50	40	30
Noise Error	15°	7°	3°	1°	1°	1°	3°	3°	4°	4°	4°	4°
Unremoved Bias Error	2°	2°	2°	2°	2°	2°	1°	1°	Less	than	1°	
Error due to 10% error in T_o	15°	4°	1°	Less	than	1°						

Table 4. Degree Error in Temperature for Sphere with Apogee 115 Km

in Table 4. After 10 Km of flight, the effect of the ten percent error has decreased to a 1° error in temperature.

The effect of C_D errors and vertical winds on temperature depends upon their effect on pressure. Since the bias C_D error profile and vertical wind profile are unknowns, the resulting pressure and temperature errors cannot be estimated. One point of interest is worth mentioning. If all drag coefficients are biased by a constant percent error, this will produce the same percent error in density and pressure, and hence, by Equation 1, will result in no error in the temperature. It is a changing bias error in C_D that will detrimentally affect temperature.

Frequency Response of Thermodynamic Data

The amount of detail that can be observed in the thermodynamic output data is determined by the frequency response of the density filter. Table 5 gives the percent of the amplitude of a 1,2,5, 10 and 20 Km sinusoidal wave in density that is retained in the output data. For example, at 70 Km a 10 Km density perturbation with amplitude X would appear in the computer printout as having amplitude .72X.

Wind Errors

The only significant sources of wind error are the noise and bias errors in velocity and acceleration resulting from the smoothing process. For a sphere apogee of 115 Km, the one sigma noise error in a wind component is estimated in Table 6. The computer program calculates the noise error in each wind component and includes both in the printout.

Frequency Response of Wind Data

The bias error in winds introduced by the smoothing function depends on the wind field itself and hence varies from flight to flight. The frequency response of the wind filter determines the degree of bias that will occur for various wavelengths. Table 7 presents this frequency response. For example, from Table 7 it

RATIO OF AMPLITUDE OF SMOOTHED DENSITY WAVE TO AMPLITUDE OF ORIGINAL
WAVE AS A FUNCTION OF ALTITUDE AND WAVELENGTH.
(ALTITUDE AND WAVELENGTH MEASURED IN KILOMETERS.)

	ALTITUDE							
WAVELENGTH	100	90	80	70	60	50	40	30
1	0.01	0.01	0.01	0.01	0.01	0.22	0.42	0.75
2	0.01	0.01	0.01	0.04	0.22	0.52	0.80	0.90
5	0.01	0.02	0.03	0.47	0.94	0.90	0.96	0.99
10	0.47	0.51	0.59	0.72	0.97	0.98	0.99	0.99
20	0.94	0.95	0.96	0.98	0.99	0.99	0.99	0.99

Table 5. Frequency Response of Thermodynamic Data

	95	90	85	80	75	70	65	60	55	50	40	30
Noise Error in wind component	35	13	5	2	2	2	1	1	less	than	1 m/	sec

Table 6. Noise Error in Wind Component for a Sphere with Apogee 115 Km

RATIO OF AMPLITUDE OF SMOOTHED SINUSOIDAL WIND TO AMPLITUDE OF ORIGINAL WIND AS A FUNCTION OF ALTITUDE AND WAVELENGTH. (ALTITUDE AND WAVELENGTH MEASURED IN KILOMETERS.)

	ALTITUDE							
WAVELENGTH	100	90	80	70	60	50	40	30
1	0.01	0.01	0.01	0.01	0.01	0.02	0.57	0.96
2	0.01	0.01	0.01	0.03	0.10	0.40	0.76	0.99
5	0.02	0.03	0.06	0.16	0.70	0.93	0.99	0.99
10	0.14	0.17	0.24	0.85	0.97	0.99	0.99	0.99
20	0.58	0.63	0.66	0.90	0.98	0.99	0.99	0.99

Table 7. Frequency Response of Wind Data

is observed that at 70 Km a 10 Km sinusoidal wave in the wind field will appear in the computed output to have only 85 percent of its true amplitude.

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